

II. "On the Spectrum of Thallium, and its Relation to the Homologous Spectra of Indium and Gallium." By HENRY WILDE, F.R.S. Received March 14, 1893.

The spectral reactions of thallium have been made the subject of observation by so many distinguished physicists as to leave little to be gleaned by further research of the spectrum of this interesting element. A strong line in the red seems, however, to have been overlooked, with one exception, in all the tables of the spectrum of thallium which have hitherto been published. Huggins would appear to have observed this line in the spark spectrum, and assigned a place for it in his table* corresponding to a wave-length of 6547 of Ångström's scale.†

For reasons which will presently appear, the existence of this line has not been confirmed by Thalén in the spark spectrum, nor by Liveing and Dewar in the arc spectrum,‡ nor by other subsequent observers.

The importance of this line in relation to the homologous spectra of other elements of the same series induced me to undertake experiments which have proved, beyond doubt, the existence of this characteristic spectral reaction of thallium.

When metallic thallium or its chloride is volatilised in the electric arc between carbon points, a red line appears in the spectrum apparently coincident with the hydrogen line C 6562. As the C line invariably appears in the spark spectrum of all metallic substances in moist air, the red thallium line was considered by me, as it would doubtless have been by others, as due to the electrolysis of aqueous vapour suspended in the atmosphere. It was, however, found that the line did not present itself in the arc spectrum of the alkaline and other metals experimented with under the same conditions. It therefore appeared to me probable that the red line belonged to the spectrum of thallium. There was, moreover, the further fact that, up to the present time, the arc spectrum of thallium below the ultra-violet was limited to the well-known Crookes' green line, and in this respect was anomalous in the simplicity of its spectrum at the high temperature of the electric arc.

That the red line was not due to electrolytic hydrogen of aqueous vapour was shown by the following experiments:—Two wide-necked phials were partially filled with strong sulphuric acid, leaving an air space at their upper ends of about two cubic inches.

* 'Phil. Trans.,' vol. 154, p. 152, 1864.

† Watts' 'Index of Spectra,' 1889.

‡ 'Brit. Association Report,' 1885.

The mouths of the phials were closed with tightly-fitting stoppers of caoutchouc, through which pairs of copper wires were thrust for the purpose of attaching electrodes of different metals in the interior of the phials. Pairs of platinum and thallium electrodes were placed in the phials respectively, which were set aside for some hours to allow the moisture of the enclosed air to be absorbed.

An induction coil, giving a 10-inch spark in air with 12 ampères of current, was used in the experiments, and the density of the spark was increased by connecting the secondary circuit with the coatings of a Leyden jar in the usual manner.

The observations were made with a direct-vision spectroscope of five prisms, fitted with an illuminated scale, which enabled comparisons to be made simultaneously between the spectral lines of different substances with great exactness and rapidity. The range of the instrument with the arc spectrum included the rubidium line 7951, and the calcium line H^2 3933, while the prismatic dispersion was such as to well divide the potassium double line 4044, 4042.

On transmitting a succession of sparks from the platinum electrodes through the dried air in one of the phials, the air lines 6602 and 6482 were very conspicuous, but there was no trace of the hydrogen line 6562 between them. When, however, the sparks were taken from the thallium electrodes under like conditions the sharp red line appeared as in the arc spectrum. The same results were obtained when similar pairs of platinum and thallium electrodes were connected in series and placed under a large glass receiver, the air in which had been dried by sulphuric acid.

The red line of thallium does not appear in the oxy-hydrogen flame, nor when the intensity of the spark is somewhat reduced by placing a vacuum tube in series with the thallium electrodes, although the brilliancy of the air lines was but little diminished.

That the red line was not due to hydrogen occluded in the thallium was shown by the following experiments:—A pair of palladium electrodes were saturated with electrolytic hydrogen from dilute sulphuric acid, through which an electric current was transmitted for several minutes. These electrodes were substituted for those of platinum in the phial of dried air; and when the sparks passed between them the strong hydrogen line C appeared for several seconds before it finally disappeared through the heating of the palladium electrodes.

A small quantity of thallium was placed on a piece of pumice under the glass receiver of an air pump, and fused *in vacuo* by the arc light condensed by a pair of Fresnel annular lenses focussed through the side of the receiver. The spectrum of the thallium fused *in vacuo*, from which all gas had been excluded, was the same as in the previous experiments.

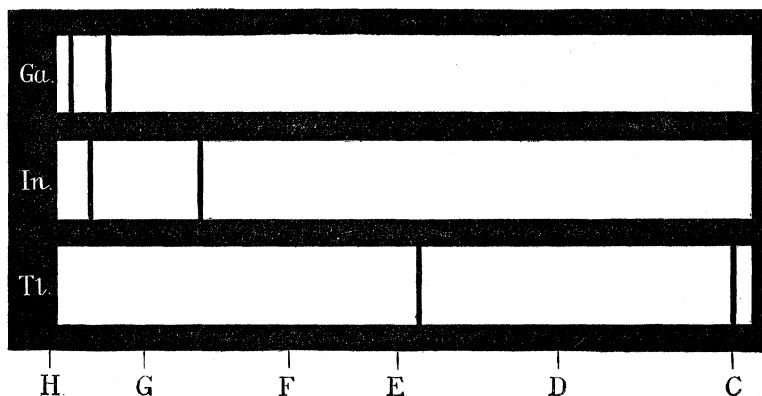
In all my observations on the spectrum of thallium I found that the red line was slightly more refrangible than the hydrogen line. The difference, however, was so small from the nebulous character of hydrogen C at atmospheric pressure, that, with the spark spectrum in moist air, the thallium line overlapped C so much as to be undistinguishable; but when the intensity of the hydrogen line was reduced, by passing the spark through partially dried air, the two lines could be distinctly recognised by the difference in their brightness.

A closer comparison of the red lines of thallium and hydrogen was now made by placing the narrow part of a hydrogen vacuum tube behind the phial containing the thallium electrodes.

The sparks through the vacuum tube and electrodes were taken simultaneously from separate induction coils. The red lines were now distinctly separated by a dark space of less width than the interval between the double sodium line D^1D^2 . The spectrum of C was less bright than the thallium line, owing to the greater distance of the vacuum tube from the slit of the spectroscope; but a more distinct line was obtained by substituting for the hydrogen tube one of carbonic acid, in which the C line appeared by the electrolysation of the residual aqueous vapour contained in the gas.

The wave-length of the thallium red line, as estimated by the difference of refrangibility of the hydrogen line, from the same electrodes in moist air, is 6560; or, 6558, as estimated from the distinct line of hydrogen in a vacuum tube.

A comparison of the arc spectrum of thallium may now be made



with the similar arc spectra of its analogues, indium and gallium. I have already pointed out that the characteristic lines of the alkaline metals and their homologues of position in the thallium series

advance towards the more refrangible parts of the spectrum in the inverse order of their atomic weights.* The correlation of the spectral reactions of thallium, indium, and gallium with the other properties of these elements is of further interest from the fact that their arc spectra (below the ultra-violet) are represented by homologous pairs of lines in the order of their atomic weights. $Tl = 204$; $\lambda 6560, 5349$. $In = 113.4$; $\lambda 4510, 4101$. $Ga = 70$; $\lambda 4170, 4031$. The intervals of space between each homologous pair of lines, as will be seen, increase in the same order. These relations are further represented in the subjoined diagram, reduced from the scale of Ångström's normal spectrum.

It would be interesting to know if the arc spectrum of scandium is represented by a similar pair of lines in the ultra-violet, as I have already suggested in the paper referred to before this elementary substance was discovered.

III. "The Potential of an Anchor Ring." By F. W. DYSON, M.A., Fellow of Trinity College, Cambridge, Isaac Newton Student in the University of Cambridge. Communicated by Professor J. J. THOMSON, F.R.S. Received March 16, 1893.

(Abstract.)

1. This paper is a continuation of some researches on rings published in the 'Phil. Trans.,' 1893. In that paper the potential of an anchor ring was found at all external points; here it is determined for internal points. The annular form of rotating gravitating fluid was considered; the stability of such a ring is investigated here. In addition, the potential of a ring of elliptic cross-section, being of interest in connexion with Saturn, is obtained. Besides this, the similarity of the methods and of the analysis employed has led me to put in this paper also the determination of the steady motion of a single vortex ring of finite cross-section and the motion of several fine vortex rings on the same axis.

2. Let the figure represent a section through the axis Oz of an anchor ring. O is the centre of the ring, C the centre of the cross-section, P any point inside the ring.

$$\text{Let } OC = c, \quad CA = a, \quad CP = R, \quad \angle ACP = \chi.$$

Then it is shown that

* 'Proceedings and Memoirs of the Manchester Lit. and Phil. Society,' 1878—1886.

Ga.

In.

Tl.

H

G

F

E

D

C

